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Paper G 11

PRELIMINARY ASSESSMENT OF GEOLOGICAL APPLICATIONS OF ERTS-1 IMAGERY FROM SELECTED AREAS OF THE CANADIAN ARCTIC

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1. Use vs Practical Application of ERTS Data:

ERTS-1 data are surrogates for information about the environment and its resources. Interpretation gives meaning to such remotely-sensed data and thus is crucial to understanding the benefits that may accrue from the whole activity.

Three levels of interpretation may be recognized and often may be employed to derive information from a single image or data format:

(1) rapid recognition, or interpretation of obvious or self-explanatory information. This level of interpretation may be undertaken by anyone who has an appreciation of scale, maps and regional geography.

(2) skilled interpretation. This level is discipline-oriented and may be carried out by a specialist or team of specialists. The interpretation is still relatively simple, often comprising only visual analysis, but it may include machine enhancement of major contrasts in spectral, spatial or temporal aspects of the data. Skilled interpretation depends upon local expertise and specialized knowledge about resources and the environment. It need not require geometric correction or special equipment and training, other than that normally received by specialists in their disciplines and in the methodologies of air-photo interpretation.

(3) automated interpretation, or spectral, spatial and temporal analysis. This level of interpretation is machine-assisted, complex and relatively expensive. The products are tables, print-outs, classifications and other data formats that must be validated by human knowledge and experience in order to provide useful information. The relevant methodologies are still largely experimental but they hold promise for providing much new information.

Interpretation per se is not an application, although it may use ERTS data. This is less a problem of semantics and more a problem of understanding. For example, anyone can use ERTS data by simply looking at an image, or other format, as an aesthetic exercise in art appreciation. On the other hand, when the observer begins to derive practical information from patterns and contrasts, such a "use" becomes a "potential application". It becomes a "practical

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application" when the data are systematically acquired in order to meet recognized economic and social goals. Thus, research to see whether ERTS-data can be used for a certain purpose is not really an application, although obviously the data are being used. Accordingly, the criterion for practical application is an imminent return on society's investment rather than an addition to scientific knowledge. Obviously the cut-off point, if not the definition, is controversial.

In this practical context, the reality of applications for ERTS-data is determined by three factors: the timeliness of interpretation, the need for the derived information and the cost-effectiveness compared to other methods for acquiring comparable information. Of these three factors, the need for derived information can be assessed now in terms of current information systems that are being used to manage the environment and resources. Need, however, is a very imprecise concept and will, unfortunately, vary from user to user. The timeliness of simple levels of interpretation is readily apparent, especially when compared with interpretation of more voluminous data, for example from aerial surveys. Moreover, the needs for new data, new information and more sophisticated interpretation will develop more slowly. Cost-effectiveness may be unreliable at this early stage in the development of orbital sensing systems; but where else can one obtain myriad data for an area of 31,000 square kilometres at the cost of a few dollars?

In the last analysis, the practicality of any application depends on the user's need for some or all of the ERTS-data. Undoubtedly, the most immediate benefits will result from the simple methods of interpretation. However, in no way does this imply that the best applications or the greatest benefits will also accrue from those methods. Such judgements are best made in the light of history.

Within this framework of immediate practical application, there is much evidence that one immediate benefit from ERTS will be improved efficiency in planning for and operation of programs of regional geological mapping. The following results, which should be considered as tentative, were obtained by simple interpretation at the skilled level using MSS band 6 only. Images were acquired under both summer and early winter conditions in two areas of the Canadian Arctic for which geological and geomorphological mapping had been completed. No field work or other calibrative studies have been conducted specifically in support of this interpretation.

2. ERTS-1 Images for Northern Yukon

In the winter image of the Richardson Mountains (Figure 1), the patterns of infrared reflectance can be readily grouped into 5 classes (A to E on

2/OCT 9 C N66-39/W134-55 N N66-40/W134-35 MSS- 6 -D SUN EL17 AZ170 203-1089-P-2-A-P-0 CCRS E-1078-20092- 6

Figure 1. ERTS-1 image of Richardson Mountains area; early winter, Oct. 9/72; sun elevation, 17°; no geometric correction; MSS band 6.

Figure 1). B & D may be equivalent classes. By comparison with the preliminary geological map (Norris et. al., 1963); it is apparent that the class A reflectance pattern represents Cretaceous shales (crosshatched unit 13 on Figure 2), class B represents a group of upper Paleozoic and Mesozoic clastics (units 8, 9 & 12 on Figure 2), class C represents two Paleozoic carbonates (units 3 & 6 on Figure 2) and class D represents the same units as class B. Class E reflectance patterns represent poorly-drained alluvium overlying Cretaceous, and lesser Devonian, clastics. The A/B, B/C and C/D boundaries are fairly sharp and they coincide with geological boundaries of certain formations or groups of formations (c.f. Figures 1 & 2). The D/E boundary is not readily defined and no correlation with mapped features is apparent. Except in this latter case, the coincidence of boundaries is remarkable as may be demonstrated by superimposing a transparency of the ERTS image on the map at the same scale. There are several noticeable discrepancies; however, their causes have not yet been established. Such discrepancies may well represent geological features that were not indicated on the preliminary map. For example, sharp contrasts along the B/C and C/D boundaries (as indicated in green on Figure 2) suggest that these boundaries may be faulted contacts.

In the more highly folded rocks of the Ogilvy Mountains area (Figure 3), similar contrasts in lighology are not as clearly indicated by MSS band 6. The high reflectance patterns at F (Figure 3) represent three Paleozoic carbonates (units 5, 6 & 7 on Figure 2) similar to those represented by class C reflectances (Figure 1). However the high reflectances at G (Figure 3) also represent Precambrian quartizites, clastics and associated rocks. The Paleozoic and Mesozoic clastics are separable from the above rocks on the basis of reflectance (compare H and I with F and G on Figure 3). Indeed, with further experience the separation of Paleozoic clastics (at H, Figure 3) from Mesozoic (at I, Figure 3) may be feasible. South of the map area (Figure 2), the highly reflective classes appear to comprise a wide variety of rocks (c.f. Green, 1972). Investigation of the multispectral characteristics of these rocks has not yet been undertaken. The characteristic patterns used in classifying the reflectances for MSS band 6 are also present on the summer images, although they are much less apparent (compare "a" on each of Figures 3 & 4).

Structural elements for all of these rocks are clearly portrayed on the early winter imagery (compare Figures 2 & 3). In particular, note the folds and faults (such as indicated in green on Figure 2) which were not recorded on the preliminary geological map. Many of these structural elements are also visible on summer imagery although commonly with less clarity (compare Figures 3 & 4). Also note that the incised valleys of the lower Peel River (at "b" on Figure 1) are emphasized on the early winter imagery. On other ERTS-images of Arctic terrain, such features as drumlins, eskers and glacial flutings

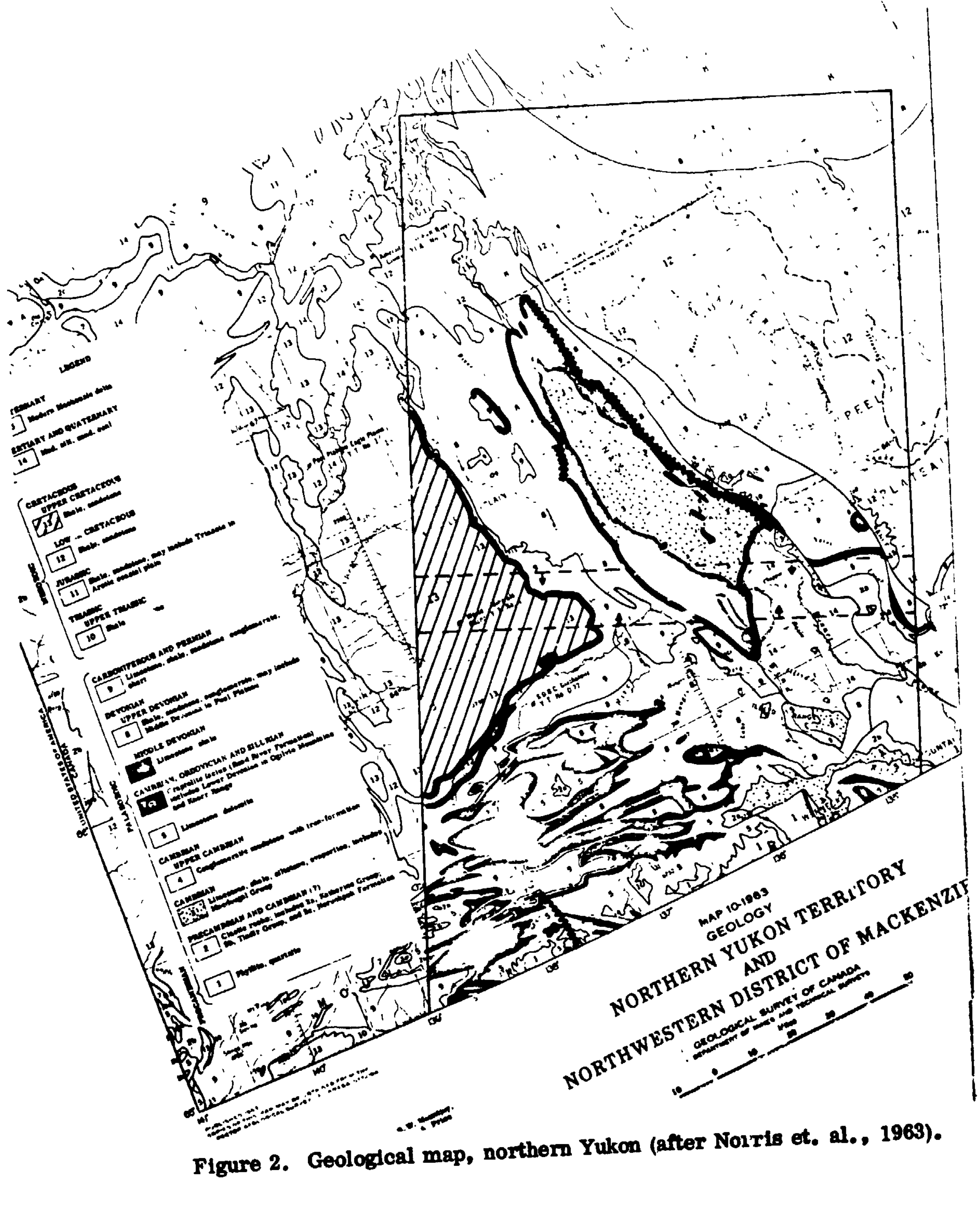

Figure 2. Geological map, northern Yukon (after Norris et. al., 1963).

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Figure 3. ERTS-1 image of Ogilvie Mountains area; early winter, Oct. 9/72; sun elevation, 18°; no geometric correction; MSS band 6

Figure 4. Image of Ogilvie Mountains area; summer, July 30/72; sun elevation, 42°; no geometric correction; MSS band 6.

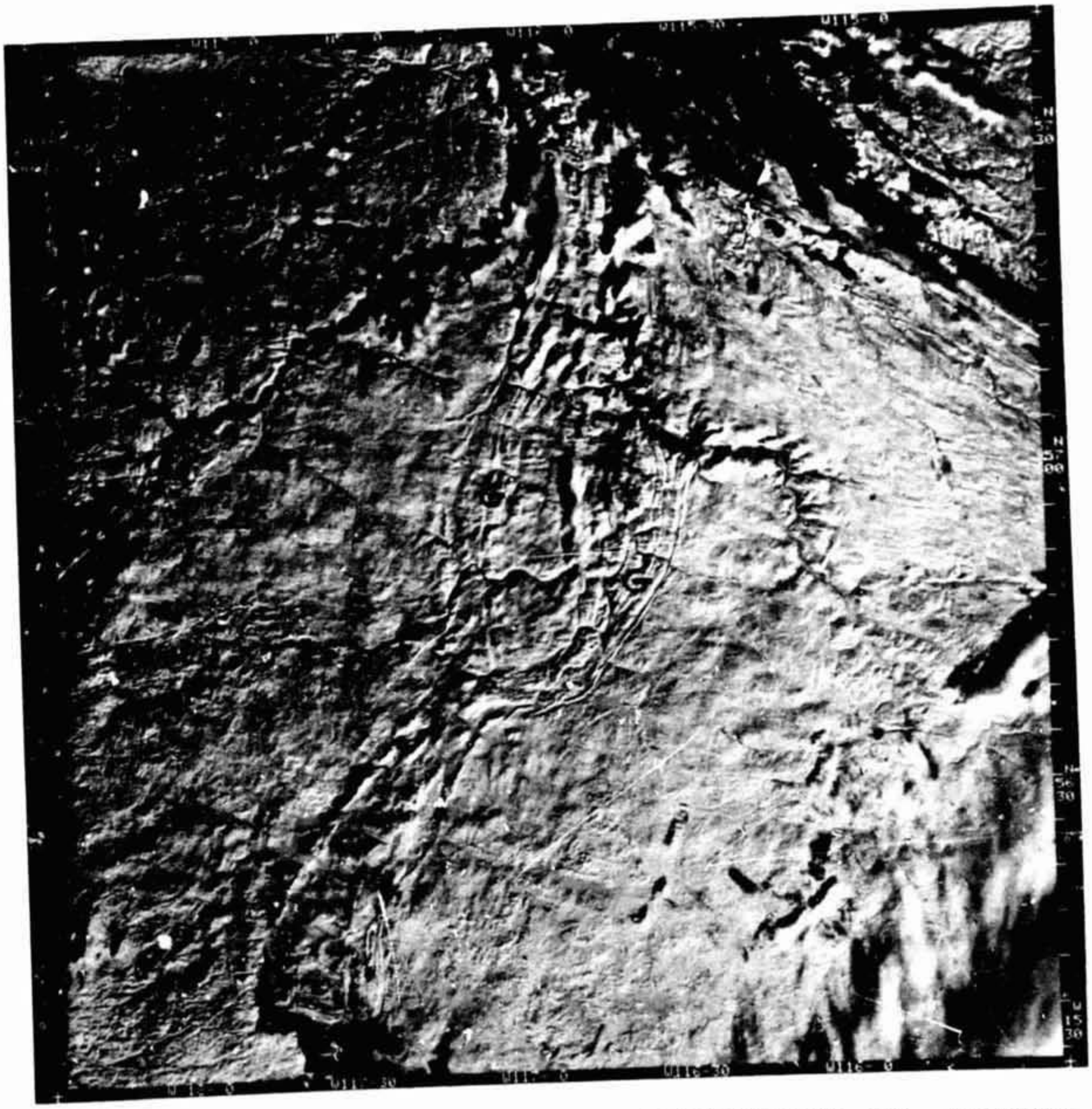
also appear to be best displayed on early winter images. On the other hand, morainic topography and oriented lakes are most clearly seen on summer images.

3. ERTS-1 Images for Bathurst Inlet area, N.W.T.

The winter image of the Bathurst Inlet area (Figure 5) clearly reveals the folded basin of Proterozoic sediments which is partly rimmed by gabbro sills (Figure 6). These Proterozoic rocks lie uncomformably on steeply dipping Archean gneisses, granites and metasediments. The sills commonly have a relief of 100-200 feet but occasionally form hills up to 800 feet in height. Note that stratification of the Goulborn quartzite (G in Figures 5 and 6) is well displayed and that the direction of dip can be inferred from the outcrop patterns of marker horizons. A number of folds and faults are visible in the Proterozoic, especially the major scarp of the Bathurst Fault zone which has relief of 300 to 1000 feet. Several interpreted and previously unmapped faults are indicated (in green on Figure 6). Many other linear features are also visible in the Archean rocks. Some of these coincide with mapped faults; others probably represent faults and joints that are not indicated on the preliminary map. These features are best displayed where associated relief is of the order of 100 feet or more. Several gabbro dykes with relief of about 100 feet are also visible on the image (compare Figures 5 and 6) although most dykes are not apparent. Pleistocene deposits are also evident, particularly eskers which rarely exceed 100 feet in height. Most of these features are not visible on the summer image (compare common areas south-west of Bathurst Inlet on Figures 6 and 7).

The high infrared reflectance (A on Figures 7 & 8) of areas within the Coronation Gulf Lowlands (Bird & Bird, 1961) is the most prominent contrast in terrain reflectance of the summer image from Bathurst Inlet. Several areas outside the lowlands have similar reflectances (e.g. B and C on Figures 7 & 8). As outlined below, these contrasts are interpreted as the consequence of major differences in vegetative cover between the abundant vegetation in the lowlands and the sparsely covered to bare uplands.

The Mackenzie Uplands (Bird & Bird, 1961) comprise bedrock with a thin and discontinuous veneer of boulder-till. The well-drained surface supports only scattered tussocks of grass, patches of lichen and occasional marshy tundra. On the other hand, the Coronation Gulf Lowlands comprise clay-till and bedrock which are largely covered by marine silts at elevations less than about 400 feet above sea level (Figure 8). The surface is poorly drained and is covered by a relatively luxurious growth of vegetation (Bird & Bird, 1961). Grasses, sedge tussocks, marshy tundra and flowering plants are abundant. Woody shrub thickets are common, especially on the west side of Bathurst Inlet.



72/OCT/ 9 C N57-07/W116-30 N N57-08/W116-30 MSS- 5 -D SUN EL25 AZ162 197-1088-P-2-A-P-8 CCRS E-1078-18260- 6

Figure 5. ERTS-1 image; early winter, Oct. 9/72; sun elevation 25°; no geometric correction; MSS band 6

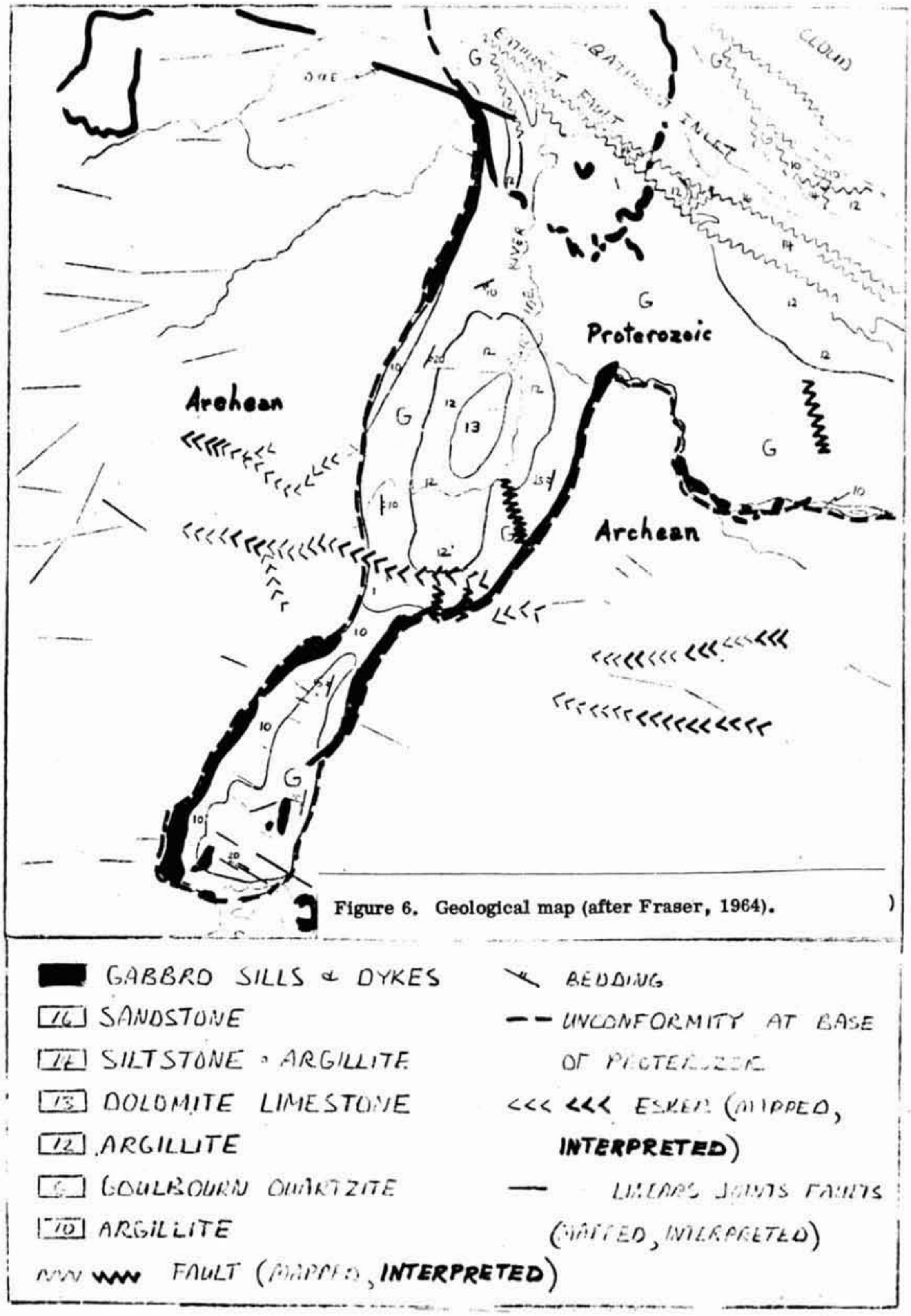


Figure 6. Geological map (after Fraser, 1964).

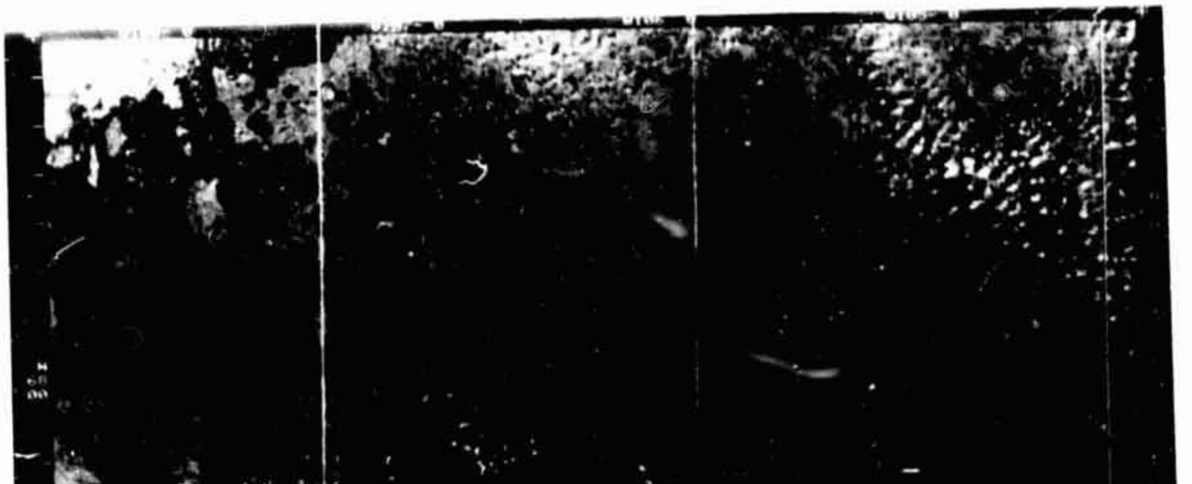


Figure 7. ERTS-1 image; summer, July 28/72; sun elevation 41°; no geometric correction; MSS band 6

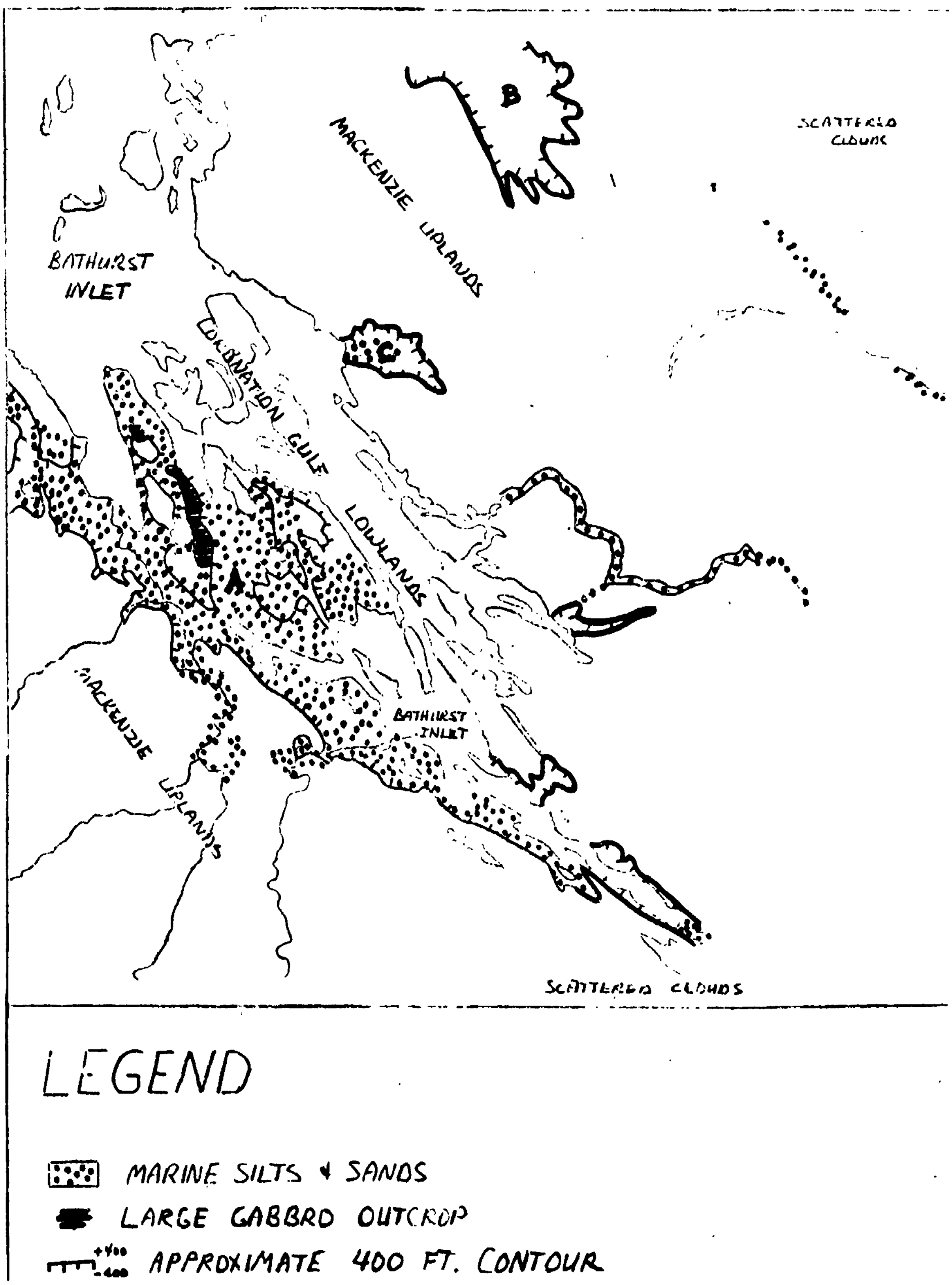


Figure 8. Map of selected surficial features (after Bird & Bird, 1961, & Fraser, 1964).

The highly reflective area at B (Figure 8) coincides with a greenstone belt surrounded by granitic gneisses. In view of the prevalent surficial deposits and low elevation, both at B and at other similar locations (in green, Figure 8), the high reflectances are interpreted as similar lowlands covered by marine silts and abundant vegetation. Several areas of low reflectance in the lowlands (north of A in Figure 7) correlate with large outcrops of gabbro.

4. Summary of Results

These preliminary interpretations indicate that early winter conditions are advantageous for observing some geological features in the Arctic because:

(1) the thin snow cover suppresses terrain "noise" from vegetation, soils, rocks and water and thus presents a uniformly reflective surface with irregularities that have geological and geomorphological significance;

(2) the low inclination of the sun accentuates textural patterns and surface irregularities with shadowing analogous to side-looking radar.

In conjunction, these two conditions of early winter serve to emphasize structure, relief and texture of the terrain surface. Where such features reflect rock-type, geological formations may be broadly classified and their boundaries delineated.

On the other hand, the summer imagery serves to delineate soil-vegetation complexes and the boundaries of water bodies more precisely than winter imagery.

In brief, both summer and early winter images provide common information useful to the geologist, but in addition each set of seasonal images provides equally useful information that is not readily derived from the other set.

5. Benefits from ERTS-1 Data

Programs of geological and geomorphological mapping for northern Canada are commonly planned in the winter and completed in about 3 months during the summer. For large areas, such rapid mapping usually requires a team of 5 or 6 professionals, support staff and several helicopters to assure representative sampling of all the rock formations. Gross structure may be outlined from aerial photos before field operations but is refined, augmented and corrected by field observations. Rock classifications depend on essential field and laboratory studies.

Had ERTS-1 images been available for the areas discussed in this paper, a significant saving in time and a more efficient mapping program might have been effected because the gross distribution of many geological and geomorphological features is readily apparent on a relatively few images. Thus ground traverses could have been more effectively organized to sample the area and to provide essential details that cannot be derived from ERTS-images. It is difficult to assess how much time might have been saved and used for other purposes. Accordingly, a realistic benefit/cost ratio is equally difficult to evaluate. However, the practicality of applying ERTS-data to assist regional mapping of both bedrock and surficial deposits seems assured despite the experimental nature of ERTS. Once a full set of seasonal coverages has been acquired for an area, that set will suffice for most geological purposes except dynamic phenomena (e.g. erosion, landslides, volcanism).

A further benefit to such mapping may accrue from enlargements of ERTS images. Preliminary assessment of enlargements to 1/250,000 and 1/100,000 suggest that they will comprise useful base maps for plotting data. Enlargements to 1/30,000 have been prepared to test their use as base maps for flying aerial surveys. Cartographic quality is not expected and the size of the geometric errors is currently being assessed.

6. Conclusions:

6.1 Immediate benefits can be achieved by simple interpretation of ERTS images to provide information about the structure and disposition of geological formations.

6.2 Simple interpretation of MSS band 6 provides no information about rock composition but, under certain limited conditions, it may assist in the broad classification of rocks.

6.3 Practical applications of ERTS-data will develop most readily where the underlying philosophy "goes beyond finding how to do things right in order to find the right things to do" (after Peter Drucker).

7. References

Bird, J. B. & Bird, M. B.: (1961) "Bathurst Inlet, Northwest Territories", Memoir #7, Geographical Branch, Dept. of Energy, Mines and Resources, Ottawa

Fraser, J. A.: (1964) "Geological Notes on Northeastern District of Mackenzie, Northwest Territories", Paper #63-40, Geological Survey of Canada, Dept. of Energy, Mines and Resources, Ottawa

Green, L. H.: (1972) "Geology of Nash Creek, Larsen Creek and Dawson Map-areas, Yukon Territory", Memoir #364, Geological Survey of Canada, Dept. of Energy, Mines and Resources, Ottawa

Norris, D. K. et. al.: (1963) "Geology, Northern Yukon Territory and Northwestern District of Mackenzie", Map 10-1963, Geological Survey of Canada, Dept. of Energy, Mines and Resources, Ottawa

Norris, K. K.: (1963) "Light Helicopter Reconnaissance-Operation Porcupine, 1962", Canadian Mining Journal, vol. 84, #11, (November) pp. 45-50